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Provides tests to evaluate the performance of tracked vehicle suspension systems, including endurance, suitability for vehicle mission, and compliance with specifications.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-101
*Test Operations Procedure 2-2-714 — 7 April 1981
AD No.

TRACKED VEHICLE SUSPENSION SYSTEMS

Page

1. SCOPE. This TOP describes procedures for assessing the performance of tracked vehicle suspension systems, including endurance and compliance with specifications. Included are tests of road wheels, idler wheels, sprockets, shock absorbers, and springing systems. Tests of tracks are contained in TOP 2-2-705.[1]**

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities. (See TOPs 1-1-011 and 2-2-611.)[2-3]

ITEM	REQUIREMENT
Various terrains	Hilly, rough, hard, sandy, muddy, etc.
Level surface	Paved, horizontal

*This TOP supersedes TOP/MTP 2-2-714, 12 February 1971.

**Footnote numbers correspond to reference numbers in Appendix C.

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ITEM	REQUIREMENT
Staggered bump course	5- to 12-inch
Spaced bump course	3-inch
Obstacle such as the 6-inch wooden bump at APG	
Ditch profile	
Vertical walls	18- to 42-inch
Washboard course	2- and 6-inch sine wave
Universal testing machine (shock absorber)	
Movie camera with telephoto lens	

2.2 Instrumentation.

ITEM	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT*
Weight scales, various capacities	$\pm$1% of reading
Calipers and micrometers (inside and outside)	$\pm$0.003 cm
Thermocouple installed in hypodermic needle	
Surface thermocouples and pyrometer	$\pm 3^\circ$ C
Durometer	N/A
Rockwell hardness tester	N/A

3. PREPARATIONS FOR TESTS.

3.1 Method.

a. Install instrumentation and points of measurement.
b. Set up experimental design for test items and personnel.
c. Prepare questionnaires or interview forms, if required by test design.
d. Review maintenance procedures.
e. Ensure that test item is in good condition for testing.

*Values may be assumed to represent $\pm$ 2 standard deviations; thus, the stated tolerances should not be exceeded in more than 1 measurement of 20.

3.2 Data Required. Record the following (for guidance, see TOPs 1-1-050, 1-2-504, and 2-2-808)[4-6]:

a. Type of springing device (e.g., torsion bar, coil, leaf, rubber, torsion elastic, Belleville springs, air, hydropneumatic, rigid)

b. Type of wheel support system (trailing, leading, or transverse arm)

c. Wheels (number, arrangement, dimensions, and type)

d. Wheelbase (distance from hub of front road wheel to hub of rear road wheel, representing length of track on ground)

e. Wheel spacing (distance between hubs or stations), minimum horizontal distance between wheel surfaces, possible interferences between wheels during various travel conditions (the 6-inch washboard course at Aberdeen Proving Ground is useful for determining this)

f. Spring constant (or rate) of spring arm and wheel assembly (in newtons per millimeter of deflection); record force and wheel position from a known reference at one position below static and three positions above static

g. Vertical wheel travel (vertical movement of each wheel hub from the static loaded position to a bump-stop position [mechanical interference limitation]); total wheel travel from static unloaded (free-hanging) to maximum position may also be recorded

h. Ground clearances (height from solid surface to underside of vehicle with combat load; for vehicles that have height-positioning control, measure the highest and lowest positions at several locations)

i. Suspension lockouts (number, type, and locking positions)

j. Pitch and damping control (devices provided and control values)

4. TEST CONTROLS.

a. Review all instructional material (including system support packages) issued with the test vehicle, and review reports of previous tests on similar items.

b. Review the safety statement provided by the developer to determine whether any hazards have been identified. If hazards do exist, write the test plan to include subtests suitable for evaluating them.

c. Observe all applicable SOPs during testing.

d. Test with new or equivalent components. Check adjustments at the beginning of the test, and at appropriate intervals throughout the test.

e. Design tests to eliminate biases of drivers and to provide consistency in vehicle loading, passenger loading, and test course terrain.

5. SUSPENSION COMPONENT TESTS. Unless specifically tested in the laboratory, suspension components are not normally evaluated independently, because they operate interdependently. Tests described herein are normally observations to be made regarding suspension components when testing the entire vehicle suspension system. Test directors planning tests of new suspension components, new tracked vehicle systems, vehicle comparisons, or components other than suspension that may be affected by vehicle suspension characteristics, should consider tests within this TOP, along with selected performance tests (TOP 2-2-600 series), obstacles (TOP 2-2-611), and endurance (TOP 2-2-506)[7]. Tests should also

be considered to determine conformance with vehicle requirements. If engineering measurements are needed regarding vehicle ride quality, crew comfort, or environment as related to component design, perform instrumented shock and vibration testing as described in TOP 2-2-808.

Occasionally, there is a requirement to examine wear and performance of a certain suspension system component very closely. Such a requirement often involves installing instrumentation and making specialized measurements. The procedures listed below are recommended for such situations.

Occasionally, a test will be required of a newly designed component. In that case, all other suspension components will be standard design items in order to avoid extraneous influencing factors, and to permit valid comparisons.

The measurements indicated in Paragraphs 5.1 through 5.5 are made only as necessary or if failures dictate further investigation. Otherwise, only ride quality, observations, failures, and maintenance are reported.

5.1 Road Wheels. Wear and deterioration rates of road wheels are the measure for satisfactory service. MIL-T-3100B,[8] an established standard for qualifying solid rubber-tired wheels, is used as a test standard. TM 9-2530-200-24[9] also provides serviceability standards.

5.1.1 Method.

a. Check the road wheel alignment for toe-in and camber. Road wheel alignment has a decided effect on wheel wear and wear on other components such as road wheel wear rings, track pads and guides, bearing deterioration, and track retention.

(1) The "as loaded" wheel toe-in is usually 0° on most tracked vehicles to provide proper track guidance and minimum wear on interfacing metal surfaces (track guides to road wheel wear rings). To check toe-in alignment, stretch a string or steel wire along the wear flanges of the wheel tire, and note the angle between the wire and the wear rings at each wheel.

(2) Improper wheel camber causes uneven wear of the road wheel tire and uneven wear across the road wheel and track road surface faces. Some vehicles are designed with a few degrees' positive camber at the road wheels so that they will reduce to 0° when the vehicle load is on the suspension and the support arm bends or rotates. If the camber is measured (usually with a quadrant), check it with and without the load of the vehicle on the support arm.

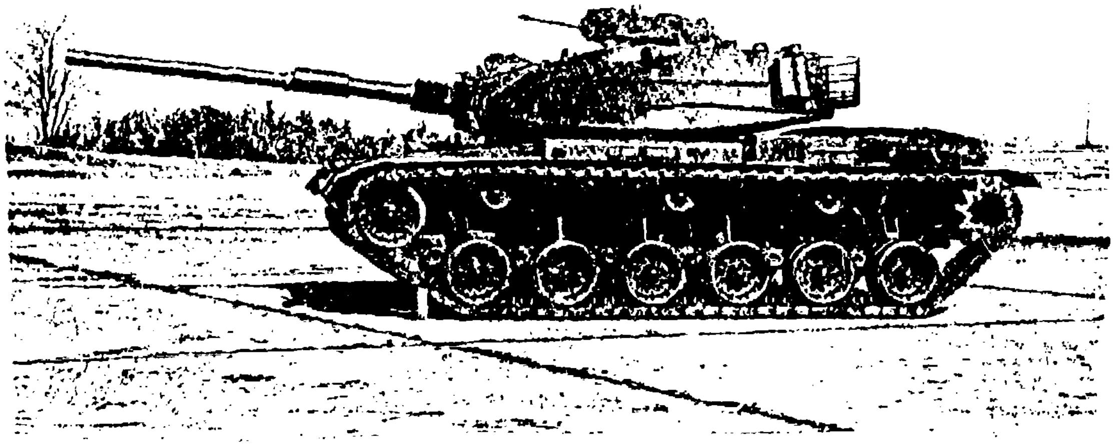

Figure 1. Typical medium tank suspension system.

The following are visible:

Track with guides	Compensating and adjustable idler
Dual road wheels	Trailing road wheel arms
Double pin track	Track support rollers
Sprockets	Shock absorbers at 1, 2, and 6 wheel positions

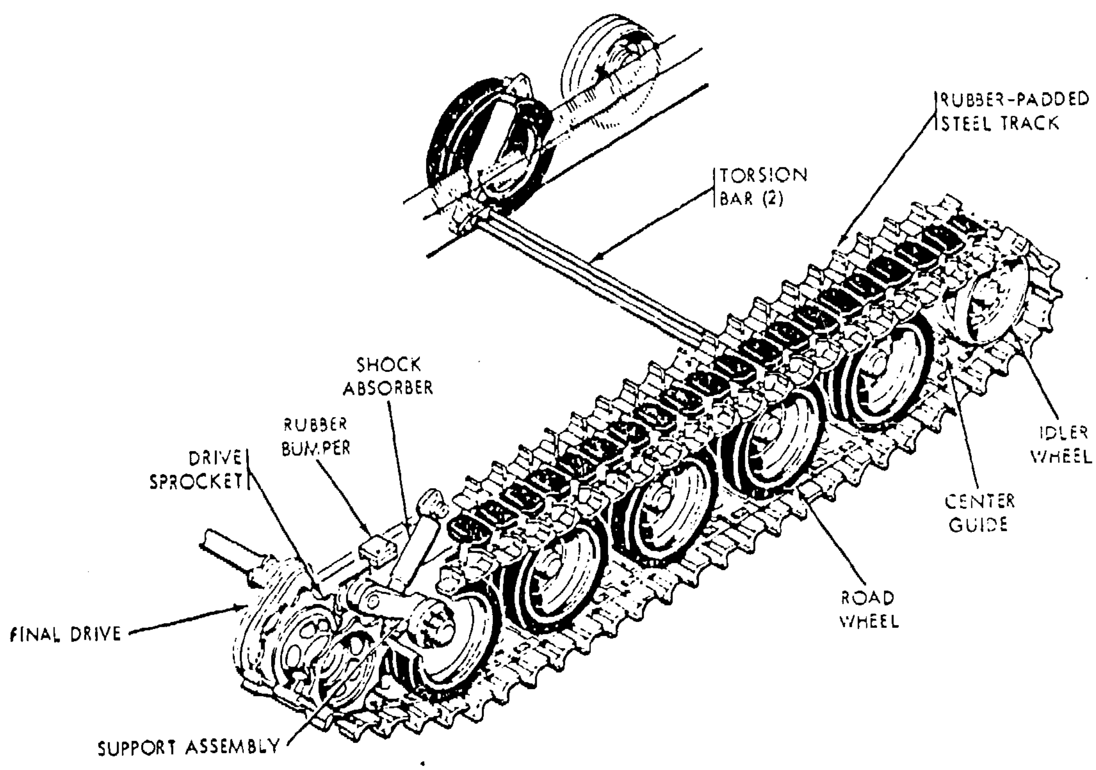

Figure 2. Typical "flat" track suspension.

The following are visible:

Single pin track
Dual road wheels
Sprockets
Steel rim, spoked idler wheels

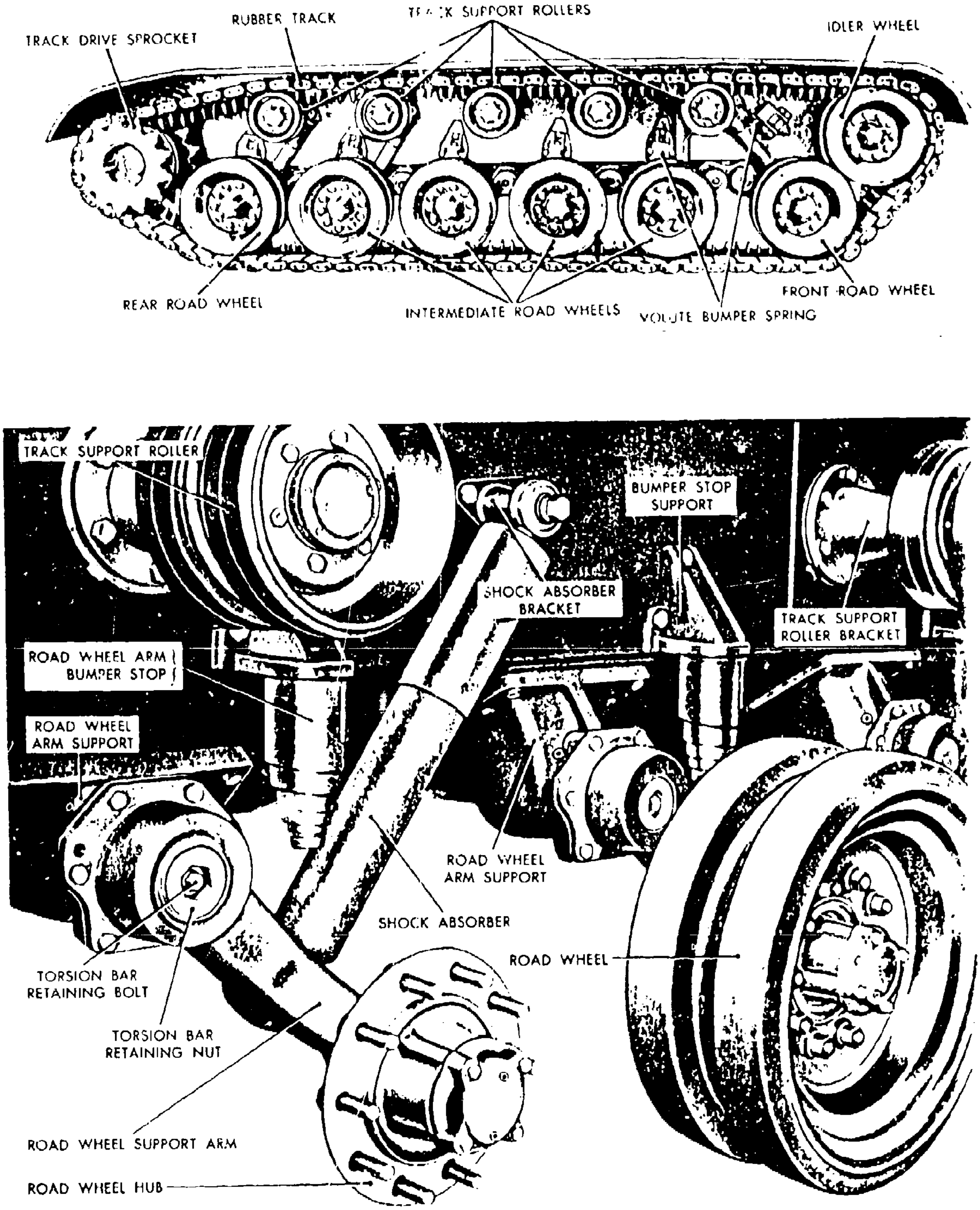

Figure 3. Suspension system components.

b. As a general rule, tire chunking, wheel cracking/deformation, and wear ring failure are the main forms of road wheel failure. A moderate amount of chunking is normal due to stones, debris, or the track center guides. MIL-T-3100B and TM9-2530-200-24 provide failure definitions and replacement criteria.

c. To determine wear rate on the wheel wear rings, drill two to four small reference holes in the face of the ring, spaced around the ring and drilled to a fixed depth to be measured with a depth gage or micrometer. (The diameter of the hole depends on the shank size of the gage.) Provide suitable clearance for measuring, should the edge of the hole become feathered. Make enough wear measurements every 800 to 1600 km to provide adequate data on the ring wear pattern.

d. Run the vehicle over test courses as described in TOP 2-2-506.

e. During testing, observe the wheels for any unusual damage such as bending, deformation, rubber chunking, cracks, or wear ring damage.

f. Obtain durometer hardness measurements. If the reading is below 60 or if heat buildup tests will be performed, continue monitoring.

g. Heat buildup tests are not normally conducted; however, if problems with chunking or blowout occur, temperature-monitor the rubber components for causal analysis.

5.1.2 Data Required. Record the following (see Paragraph 5.1.1):

a. Wear measurements and temperature buildup data
b. Structural failures
c. Mileage of operations and fuel consumed on each test course

5.2 Idler Wheels. One of the main differences in the various suspension system designs is the configuration and mounting of the idler wheels. Therefore, it is difficult to provide a general description to cover all designs or to standardize a test procedure for this component.

If frequent damage to the idler wheel or mounting occurs, bottoming on obstacles during cross-country operations may be the cause. This would be reason to instrument for field shock and vibration testing using triaxial accelerometers at the idler mount, in accordance with TOP 2-2-808.

5.2.1 Method.

a. Tighten track to proper tension.

b. Operate the vehicle over test courses as described in TOP 2-2-506.

c. Periodically check track tension in accordance with the operator's manual.

5.2.2 Data Required. Record the following (see Paragraph 5.2.1):

a. Mileage of operations on each type of course
b. Initial tension of track and tension after various periods of operation

c. Observations relative to durability of the idler wheels and the ability of idler wheels to guide the track to the sprocket.

5.3 Sprockets. A sprocket is evaluated by determining its relative ability to perform without excessive wear, noise, or vibration on either the track or the sprocket. The engagement pattern is evaluated by the smoothness of engagement and disengagement during the entire service life of the sprocket.

5.3.1 Method.

a. Before starting, perform Rockwell hardness tests on the face of sprocket teeth.

b. Operate the vehicle over test courses as described in TOP 2-2-506.

c. Use one of the following methods (listed in order of preference) to measure wear:

(1) Full-scale tooth profiles: make a template plot of original tooth profile. Repeat every 800 to 1600 km, and superimpose one upon the other for visual comparison and measurements along the profile.

(2) Measurements of the tooth: mark the tooth with permanent reference points with a center punch. Measure dimensional changes at appropriate mileage intervals.

d. Observe smoothness of sprocket operation, including performing several sharp turns on various surfaces, forward and backward, as well as routine operations on the test courses.

NOTE: For unusual sprocket designs, test procedures should be developed to evaluate their particular characteristics.

5.3.2 Data Required. Record the following, as obtained in Paragraph 5.3.1:

a. Wear measurements and hardness
b. Mileage operated on each type of course
c. Mileage at which sprockets are reversed
d. Observations regarding smoothness of sprocket operation

5.4 Shock Absorbers. Shock absorbers must be properly matched with the springing system; this is especially important in contemporary high-speed tracked vehicles that incorporate high wheel travel with low spring rates. Testing a vehicle includes determining the suitability of the shock-absorbing devices. Criteria are their endurance, overall suspension match, and damping characteristics.

Internal failures that can occur include seal deterioration, damaged or displaced valves, broken springs, pressure-ruptured cylinder or reservoir, and similar defects. External failures are those resulting from outside causes such as striking or jamming of the test item by debris, rocks, or excessive packing of earth. Failures due to dimensional limitations are not as readily recognized; for instance, a road wheel arm

design provides for a positive stop after the arm has moved through a specific arc, to prevent exceeding spring limitations, shock absorber bottoming, and road wheel interferences with the hull or other suspension components. Due to manufacturing tolerances or normal wear on the stop elements, these limits may be exceeded. Dimensional measurements are made with the arm compressed through an arc if a failure occurs that includes broken internal parts, cracked welds or cylinders, or similar conditions.

Plan suspension testing to suit the components involved. Washboard courses, vertical walls, and spaced obstacles are useful, particularly in comparison with standard equipment. Interferences, functioning of stops, and temperature reaction of shock absorbers are specifically observed. Extreme vibrations are often induced by operation over rough, hard surfaces. Operation at temperature extremes of 49° and -46° C should be checked during natural environmental tests at places such as Yuma Proving Ground and Cold Regions Test Center.

5.4.1 Method.

Run the test vehicle over test courses as described in TOP 2-2-506.

a. Effects on shock absorber seals:

(1) Take operating temperatures; pressures may also be taken at the discretion of the test director.

(2) Select one shock absorber as a reference to obtain cooling rate for making temperature/time corrections on all shock absorbers.

(3) Insert taps through the side of the unit and record pressure while vehicle is operating; temperature may be recorded using thermocouples attached to the body of the shock absorber.

(4) Record temperature and time of reading for all shock absorbers. NOTE: A field expedient for temperature measurement is a surface thermocouple pyrometer.

b. Shock absorber effects on ride quality:

(1) Subjective and photographic evaluations:

Conduct instrumented studies or subjective evaluations (i.e., jury trials) by making changes in the damping unit. The subjective evaluations require a large sample of individual responses (see Appendix B). A basis of subjective comparison is established, i.e., with and without shock absorbers, with different numbers and locations of shock absorbers, or with various shock absorber control values. Photographic records obtained as described in Paragraph 5.5.1.b are made when appropriate.

When making photographic and subjective evaluations, test with the same vehicle and personnel. Make successive test runs within the shortest elapsed time possible (personnel must use the experience of one ride to evaluate the next, and their subjective standard for comparison remains constant for a short time).

(2) Laboratory testing:

Conduct laboratory tests on shock absorbers to determine functioning under controlled conditions. The effectiveness of a shock absorber depends on the mechanical energy absorbed (the response value) as the device is exercised. A change in the response of a shock absorber during extended service degrades the service life capabilities. Such changes are determined by laboratory and field tests (TOP 2-2-808).

A universal shock absorber testing machine is used to perform the laboratory tests. By exercising the shock absorber at various displacements and frequencies (determined by test criteria), the machine is used to periodically check for deterioration of shock absorber performance during endurance testing. NOTE: Manufacturers rate shock absorbers according to their effective force in compression and rebound at a specified displacement and frequency. The force absorption characteristics vary slightly by manufacturer. The ratings for military shock absorbers are checked over a 7.6-cm displacement at 50 cycles per minute, and at a temperature of 38° C, unless designated otherwise on the drawing or specification.

Mount the shock absorber on the testing machine, oriented in the same manner as on the vehicle.

Place a load cell at an end mounting of the shock absorber to measure force.

Place a thermocouple patch on the side of the reservoir to measure temperature.

Connect a strip chart recorder to the testing machine to record time/force data.

Exercise the shock absorber at the displacements and frequencies determined by test objectives. Do not over-exercise, bottom, or overheat.

To determine forces at various operating temperatures, raise or limit the temperature by increasing or reducing the cyclic rate. (The loading on a shock absorber varies with changes in temperature of the fluid.)

5.4.2 <u>Data Required</u>. Record the following:

a. Mileage of operations on each type of course

b. Type and damping characteristics

c. Failures (internal, external, and those resulting from dimensional limitations)

d. Operating temperature or pressure as applicable (seal malfunctions)

e. Subjective evaluations per number and location of shock absorbers used, and other data to identify each subjective evaluation.

f. Laboratory test cycle rates, compression and rebound forces, displacements, frequencies, and temperatures.

5.5 <u>Springing Systems</u>. Evaluation of springing systems includes consideration of the springs and springing elements, wheel arms or supports, suspension assembly configuration, and interactions among the various

components. There is no established standard for evaluating a springing system; however, the methods described below have been used successfully in tests at Aberdeen Proving Ground. To obtain engineering data for evaluating a system or comparing two systems, obtain displacement/time measurements from photographs or potentiometers to measure road arm angle. Evaluate springing systems, based on subjective evaluations obtained during ride.

The suitability of the springing system on a tracked vehicle is related to the displacement and frequency of hull motion about three axes. A test course of single fixed bump configurations is used to assure the same input excitation for any vehicle or springing system. (Fixed multiple bump arrangements are not satisfactory for this type of evaluation, as suitable techniques for establishing the proper spacing of the bumps have not been developed. Such spacing depends on a combination of wheelbase length, spring rates, and vehicle pitch rates to obtain comparable vehicle functioning.)

5.5.1 Method.

a. Operate the test vehicle over courses as described in TOP 2-2-506.

b. Photographic evaluation: To obtain displacement values and vehicle pitch angles, take measurements from successive frames of motion pictures of the vehicle crossing the fixed bump. Pitch rate, angular or vertical accelerations, damping decrement, and other vehicle response data associated with the springing system are derived from these measurements.

(1) Use the horizontal line of the roadway for the reference. If it does not register in the picture frame, establish a reference rail or other line above, but parallel to, the roadway within the frame.

(2) Erect one or more vertical ground reference poles at a known height and position to align with the vertical reference on the vehicle.

(3) Place two vertical poles of known distance apart along the roadway ahead of the 6-inch bump* to provide references for accurate timing of vehicular speed by means of the camera framing rate, a separate stopwatch, or a fifth wheel observation.

(4) Establish two reference points of known distance apart on the vehicle chassis sides to be photographed. These points are near the front and rear of the vehicle, both at the same height above the roadway (same horizontal plane), and at a convenient distance apart (3, 4, or 5 meters) to simplify computations. (For convenience in viewing the film, these reference points can be joined with a white line and the vertical lines scribed.)

(5) Place the camera as far from the course as possible (180 to 275 meters) perpendicular to the course from the trailing end of the

*An obstacle like the 6-inch wooden bump at APG, that is used for gun stabilization tests.

bump. (The greater the distance to the camera, the less the parallax error introduced because the angle of camera sweep and the proportional change in distance from camera to vehicle as it crosses the front are reduced.)

(6) Use a telephoto lens to fill the frame to the greatest extent possible with the vehicle to include horizontal and vertical references.

(7) Set up the camera so that it moves laterally through the same plane as the roadway or horizontal reference line. (8) Use a frame frequency (somewhere between 64 and 128 frames per second) that permits a suitable number of sequential pictures for obtaining smooth curves. A constant camera film feed speed permits sequential timing (e.g., with a vehicle traveling 32 km/hr initially and a camera frame speed of 64 frames per second, the vehicle will travel 14 cm horizontally between each frame, and the vehicle speed changes over the bump can be computed by measuring the forward progress). There are fiducial marks on the exposed film. Velocities and accelerations can be computed only if the event is accurately timed.

(9) Read the film on film analyzers, plotting displacement of front, rear, or center of gravity of the vehicle versus distance or time, and pitch angles versus distance or time.

(10) From these data, compute vertical and angular velocity, pitch attenuation or damping decrement, and acceleration. NOTE: Large displacements and pitch angles do not necessarily mean discomfort or undesirable suspension arrangement. If the frequencies are low enough, the ride may be pleasant and cargo will not be affected. On the other hand, low spring rates must be accompanied by high wheel travel and auxiliary damping to prevent severe bottoming shocks.

c. Subjective evaluations: An immediate and direct evaluation of a springing system can be obtained from a properly conducted subjective evaluation (jury trial) of ride quality since the ride quality of a vehicle is closely associated with the characteristics of the springing system, and is based on physiological limitations and human factors. Subjective evaluation procedures are described in Appendix B.

5.5.2 <u>Data Required.</u> Record the following:

a. Displacement and pitch angle data from photographs
b. Subjective evaluation ratings
c. Structural failures, if any
d. Mileage of operations run over each course
e. Fuel consumed on test courses

6. DATA REDUCTION AND PRESENTATION.

a. Include photographic records of operations and failures in test documentation.

b. Use tabulations, graphs, or curves to report data versus significant parameters such as:

(1) Physical characteristics versus those of standard similar item.

(2) Wear rate measurements versus test mileage
(3) Rockwell hardness changes versus test mileage
(4) Structural and other failures versus test operations
(5) Fuel consumption versus operation for test and standard comparative items

c. Tabulate, rate, and analyze the subjective evaluation ratings as described in Appendix B.

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APPENDIX A
SUSPENSION SYSTEM COMPONENTS

Road Wheels.

Road wheels on tracked vehicles are generally mounted singly or in pairs. A track with single road wheels is usually designed with a double row of guides spaced with the wheel in between; wear surfaces or flanges are incorporated on both sides of the wheel. If the road wheels are mounted in pairs, a single row of guides and a single wear surface on each wheel are sufficient.

The orientation and alignment of road wheels is expressed in two terms:

Camber - the angle by which a wheel deviates from the vertical position

Toe-in - the horizontal angle by which a wheel deviates from the straight-ahead position

Idler Wheels.

The idler wheel supports the track at either end of the vehicle, opposite the drive sprocket, and re-directs the track toward the sprocket. It maintains proper track tension by incorporating a track tension-adjusting or -compensating device.

Sprockets.

Sprocket teeth or protuberances engage with the track to force the vehicle to move along the ground. The sprocket provides track guidance to reduce possible track-throwing in the vicinity of the sprocket.

The anticipated service life of a sprocket is intended to be at least as long as the life of the track. The sprocket is designed to be reversed, i.e., to permit driving against both wearing faces by turning the sprockets around or by mounting them on opposite sides of the vehicle. The sprockets are reversed after about two-thirds of the expected track life. To extend the life of the sprockets and track, the interfacing metal contact areas are hardened during manufacturing. Although sprocket life depends on this hardened surface, the core of the drive surface needs toughness to withstand the high-impact loadings. After the wear extends through the hardened coating, the wear rate increases.

NOTE: Although not necessarily relevant to sprocket service life, the pattern of impact between the track and sprocket may become an important factor in evaluating the drive train and suspension of the vehicle. The sprocket impacts with the track; in some track/sprocket designs, there is one impact for each tooth engagement, while in others, there are two impacts: one when the tooth engages and one when the track is seated on the sprocket. This sprocket engagement impact pattern can influence the sprocket and track wear pattern, and is the major contributor to vehicle

vibration amplitudes and frequencies (TOP 2-2-808). Designs that reduce the track/sprocket impact loads, such as rubber sprocket cushions or rubber-covered guide wheels (namely, M113, M548, M114, and M116), result in longer sprocket and track life, reduced noise and vehicle vibration, and improved ride comfort.

Shock Absorbers.

Shock-absorbing devices are incorporated in a suspension system to attenuate wheel motion and provide vehicle pitch control. Shock absorbers dampen a portion of the energy peaks during rapid wheel travel or violent vehicle pitching. A damping control suitably matched to a vehicular design enhances the stability of the vehicle for operation over rough terrain.

A shock absorber dissipates the impact energy of motion without returning it as motion. Devices commonly used on military vehicles include the hydraulic shock absorbers that convert mechanical energy to heat by throttling oil through an orifice (either a piston operating in a cylinder or a rotary vane mechanism), and the friction snubber that absorbs mechanical energy by one friction surface rubbing over another. Thus, through dissipation of heat, the pitching motion of the vehicle is attenuated.

Knowledge of the function and various effects of shock absorbers is essential to conduct suitable tests of these items. Characteristics considered are double- or single-acting velocity-sensitive or constant-level absorption, and absorption level change controls. For maximum pitch control of tracked vehicles with the least number of units, shock absorbers are mounted on the front and rear wheels where the greatest wheel travel and highest impact loadings occur. Shock absorbers at intermediate positions are less effective in damping vehicular motion, and mounting at these locations is determined by the degree of vehicular control required.

APPENDIX B
SUBJECTIVE EVALUATION PROCEDURES
(JURY TESTS)

Subjective evaluations are not limited to a springing system or components, but are used for many aspects of the person/machine relationship. The procedures described below are used as a guide when subjective evaluations (jury tests) are referred to by any other Aberdeen Proving Ground TOP (e.g., TOP 2-2-808).

1. TEST PLANNING. In subjective evaluations, a comparison is made of the opinions of a group of people riding in the test vehicle over selected courses at controlled speeds. The specific subjective evaluation is designed to achieve unbiased results. Test results are reduced to numerics for assessment. The following factors are considered in test planning:

a. Personnel - the group of people includes experienced personnel such as operators, test engineers, and supervisors, as well as inexperienced personnel. If a comparison vehicle is not used in the evaluations (e.g., when assessing ride quality with and without shock absorbers [Paragraph 5.4.1b]), only experienced personnel are used.

b. Vehicles - for most applications, a suitable subjective evaluation is based on a comparison of at least two vehicles: the test vehicle and a current standard vehicle of the same type. Other vehicles may be added, usually no more than five.

c. Courses - fixed test courses may be included to obtain specific input. Several random input courses are also included. In most cases, several of the less severe cross-country courses and a paved roadway are satisfactory (see TOP 1-1-011).

d. Orientation of personnel - the group is oriented before testing as to what the schedule is; what they are to observe; how they should observe; and what information they are to report, e.g.:

> Many factors combine to constitute ride quality. Some are closely related but are evaluated separately to ensure subjective judgments by each person and the test director. Among these elements are gross motion (pitch and bounce), low amplitude/high frequency motion (vibration), and sound level (noise). Likewise, judgments are made of roll and yaw motion. Pitch and bounce occur in combined motion, but are subjectively separated by each person. Vibration and noise result from a common track slap phenomenon, but each is sensed by different parts of the human body. Noise has a disproportionate influence on ride quality judgment, i.e., an uncommonly noisy vehicle may be judged to have a much harsher ride than it actually has. The group member observes this effect by covering his/her ears, allowing the body to sense the motion values of

the ride, and then uncovering his/her ears and noting the difference in bodily reaction.

e. Operating conditions:

(1) The test is conducted in favorable weather on suitable terrain.

(2) A full vehicle crew is selected for each trip.

(3) The group rides in the baseline vehicle first, immediately followed by riding in the test vehicle; intervals between rides in comparison vehicles are kept minimal.

(4) Each person rides in a similar position in each vehicle.

(5) Courses and speeds are the same for each vehicle and each person.

2. REPORTING TEST RESULTS. A simple evaluation form is preferred for completion by each group member, requiring only a checkmark in the appropriate block, but providing space for remarks (see Figure B-1). Note that sound level (noise) is separated from vibration on the form so that the group will think of them separately for the reasons cited in 1d above.

3. GRADING TEST RESULTS. Grading the observed responses is necessary to establish a means of assessment. Since it is difficult to finely divide responses, gross observations are preferred: mild, moderate, or excessive. It is suggested that these adjective ratings be weighted: mild - 10; moderate - 5; or excessive - 0, as in Figure B-2. Any desired weighting is used. Figure B-2 shows a sample form suitable for tabulating the individual ratings and recording the overall function ratings.

To illustrate the use of Figure B-2, if 8 people are rating, with 7 rating vehicle 1 pitch "mild" and 1 person rating it "moderate", the overall function rating for vehicle 1 pitch would be:

$$\begin{aligned} 7/8 \times \text{weight } 10 &= 8.75 \\ + 1/8 \times \text{weight } 5 &= \underline{0.625} \\ \text{Total} &= 9.375 \end{aligned}$$

The four functions may also be averaged to obtain an overall rating for the vehicle.

4. STATISTICAL ANALYSIS OF SUBJECTIVE EVALUATIONS. The "overall function ratings" in Figure B-2 must be subjected to a statistical test in order to determine whether the differences in ride quality of the vehicles are significant. The statistical test employed is often referred to as a "test of homogeneity of parallel samples". This technique is described in AMC Pamphlet 706-111, Paragraph 9-2, page 9-6, and presented in abbreviated form below. If the statistical test does not indicate a significant difference, the observed differences between vehicles cannot be distinguished from the chance variation inherent to the procedure, material, and test conditions.

To apply the statistical test, prepare a table as in Figure B-3 below for each function (pitch, bounce, etc.). The data are obtained from the form shown in Figure B-1 by combining the evaluations for each course and group member.

Location in Vehicle:						
I. GENERAL RIDE CHARACTERISTICS						
	Test Vehicle No. 1			Test Vehicle No. 2		
	Mild	Moderate	Excessive	Mild	Moderate	Excessive
Pitch						
Bounce						
Vibration						
Remarks:						
II. SOUND LEVEL						
	Test Vehicle No. 1			Test Vehicle No. 2		
	Mild	Moderate	Excessive	Mild	Moderate	Excessive
Remarks:						

Figure B-1. Subjective Evaluation Form.

Function	Vehicle	Consolidated Individual Ratings (by No. of raters per vehicle)			Overall Function Rating[a]	Statistically Different from Test Vehicle?[b]
		Mild	Moderate	Excessive		
Pitch	1					
	2					
Bounce	1					
	2					
Vibration	1					
	2					
Noise	1					
	2					

[a]Computation: overall function rating =

% of jury rating mild x 10
+ % of jury rating moderate x 5
+ % of jury rating excessive x 0

[b]Determine according to Paragraph 4.

Figure B-2. Form for consolidating subjective evaluations.

Vehicle	Mild	Moderate	Excessive	Total
No. 1	f_{11}	f_{12}	f_{13}	n_1
No. 2	f_{21}	f_{22}	f_{23}	n_2
.	.	. .	.	.
.	.	.	.	.
.	.	.	.	.
No. m	f_{m1}	f_{m2}	f_{m3}	n_m
Total	c_1	c_2	c_3	n

Figure B-3. Ride characteristics versus vehicle.

The entries in the body of the table are obtained as follows: 11 is the number of "mild" ratings for vehicle 1; 12 is the number of "moderate" ratings; and 13 is the number of "excessive" ratings. 1 is the total number of ratings given to vehicle 1. Entries for other vehicles are obtained in the same way. The column totals are denoted by 1, 2, and 3. The total number of ratings for all vehicles in the comparison is n. The following statistics are calculated thus:

$$x^2 = n\left(\sum_{i=1}^{m}\sum_{j=1}^{k}\frac{f^2_{ij}}{n_i C_j} - 1\right)$$

x has a chi-square distribution, approximately, with 2 (m-1) degrees of freedom. The statistic x is compared to the 100(1-a) percentile of the chi-square distribution with 2(m-1) degrees of freedom. If a is chosen to be 0.10, the significance point is X (.90). If x $\geq$ X (1-a) with 2(m-1) degrees of freedom, it is concluded that the vehicles differ in ride quality relative to the function under consideration. If x < X (1-a), it is concluded that the vehicles do not differ significantly. This procedure is repeated for each function (pitch, bounce, etc.) under consideration.

APPENDIX C
REFERENCES

1. Materiel Testing Procedure 2-2-705, Tracks, 1 July 1970.

2. Test Operations Procedure 1-1-011, Vehicle Test Facilities at Aberdeen Proving Ground, 17 March 1976.

3. Materiel Testing Procedure 2-2-611, Standard Obstacles, 10 April 1980.

4. Test Operations Procedure 1-1-050, Vibration Testing, 4 March 1972.

5. Test Operations Procedure 1-2-504, Physical Characteristics, 31 October 1972.

6. Test Operations Procedure 2-2-808, Field Shock and Vibration Tests of Vehicles, 26 September 1979.

7. Test Operations Procedure 2-2-506, Endurance Testing of Tracked and Wheeled Vehicles, 9 September 1976.

8. MIL-T-3100B, Tires, Solid Rubber, and Wheels, Solid Rubber-Tired, 22 April 1963.

9. TM-9-2530-200-24, Standards for Inspection and Classification of Tracks, Track Components, and Solid Rubber Tires, July 1976.